

National Aeronautics and Space Administration

Physiological Health Challenges for Human Missions to Mars

Peter Norsk, M.D., dr. med.

Chief/Element Scientist
USRA/NASA-JSC





Disclosure Information:

I have no financial relationships to disclose.

I will not discuss off-label use and/or investigational use in this presentation.



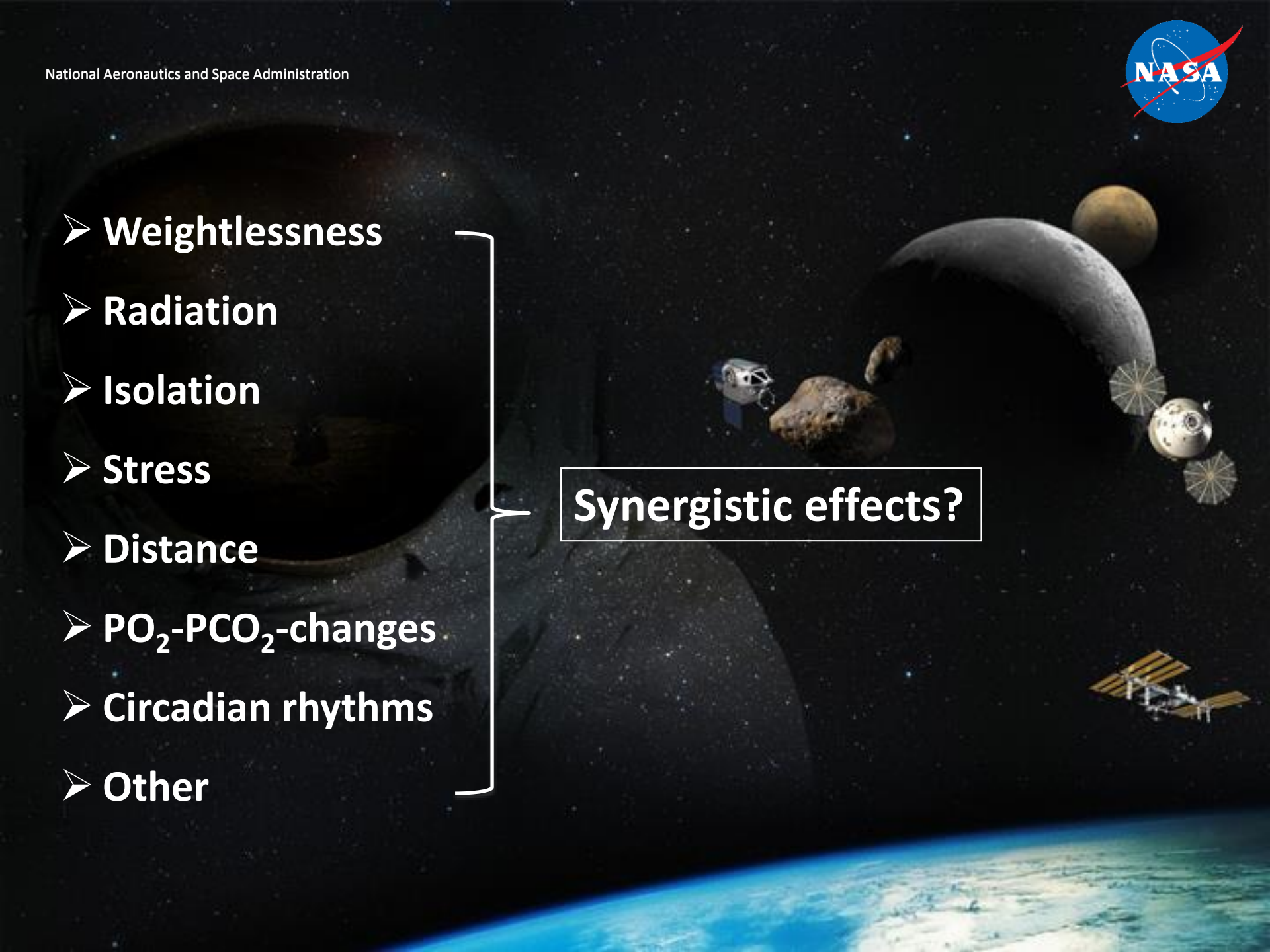
- **Weightlessness**
- **Radiation**
- **Isolation**
- **Stress**
- **Distance**
- **PO₂-PCO₂-changes**
- **Circadian rhythms**
- **Other**



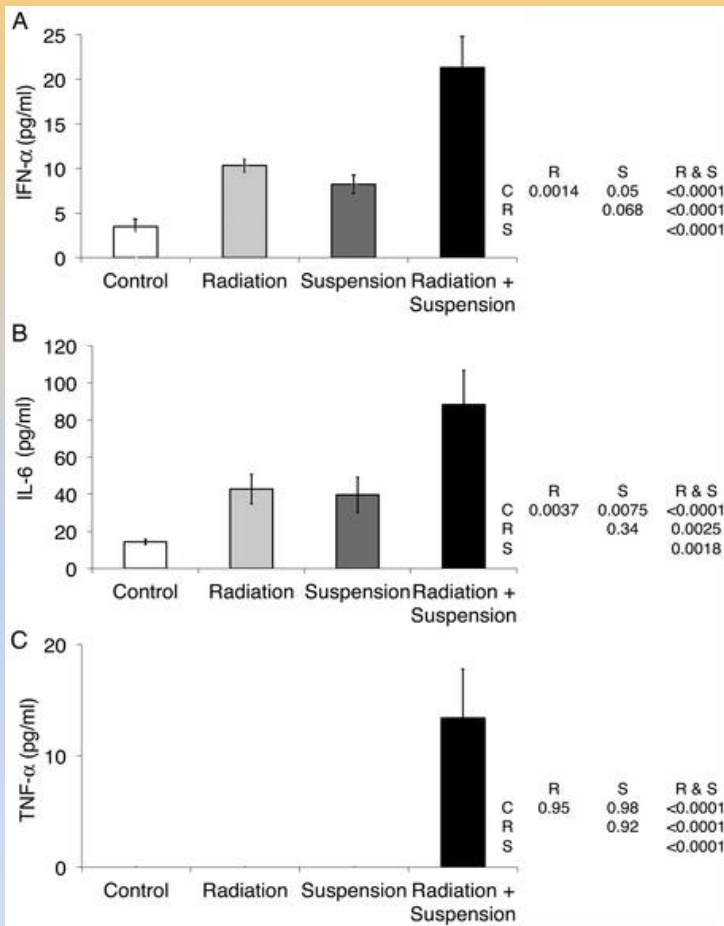


- **Weightlessness**
- **Radiation**
- **Isolation**
- **Stress**
- **Distance**
- **PO₂-PCO₂-changes**
- **Circadian rhythms**
- **Other**

Synergistic effects?



Examples



An example of synergistic effects of 0 G-simulation and radiation (2 Gy)

Zhou Y, Ni H, Li M, Sanzari JK, et al. (2012) PLoS ONE 7(9): e44329. doi:10.1371/journal.pone.0044329

<http://www.plosone.org/article/info:doi/10.1371/journal.pone.0044329>

Simulated weightlessness and ionizing radiation: bone and muscle effects

(Globus et al. 2014)



Rodent Hindlimb Unloading (HU)



Ionizing Radiation



BONE

MUSCLE

HU AND RADIATION (DOSE-DEPENDENT) EACH CAN CAUSE:

- decrements in density and architecture
- weaker mechanical properties; greater propensity to fracture
- increased bone resorption by osteoclasts
- impaired bone formation by osteoblasts
- depletion of progenitors

HU: reversible

RAD: ? irreversible

-HU CAUSES:

- muscle fiber atrophy
- switch from slow to fast-type fibers

-RADIATION (DOSE-DEPENDENT) CAN CAUSE :

- increase in smaller diameter fibers
- more fibers containing central nuclei
- satellite cell apoptosis

Present platform in LEO

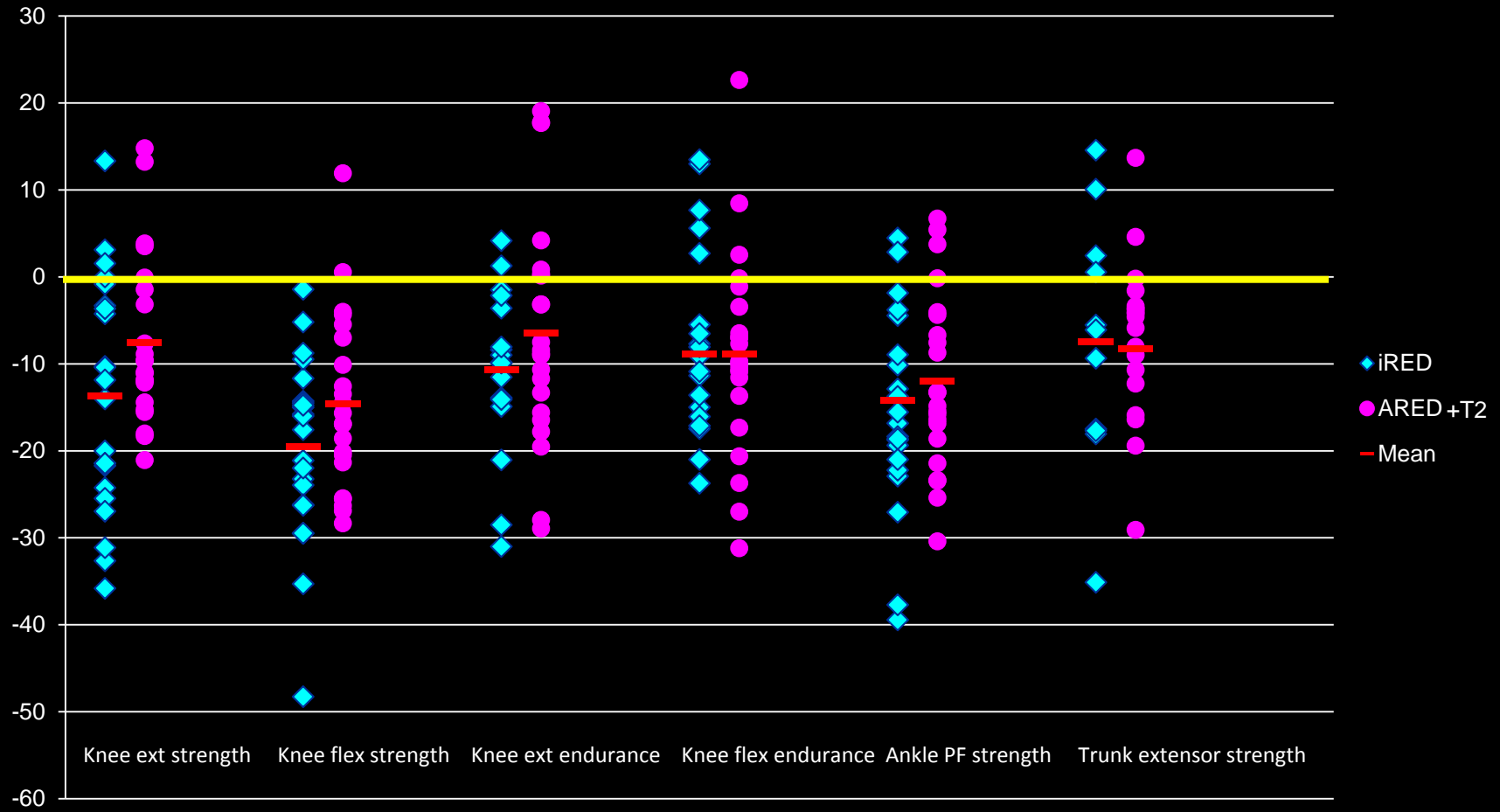






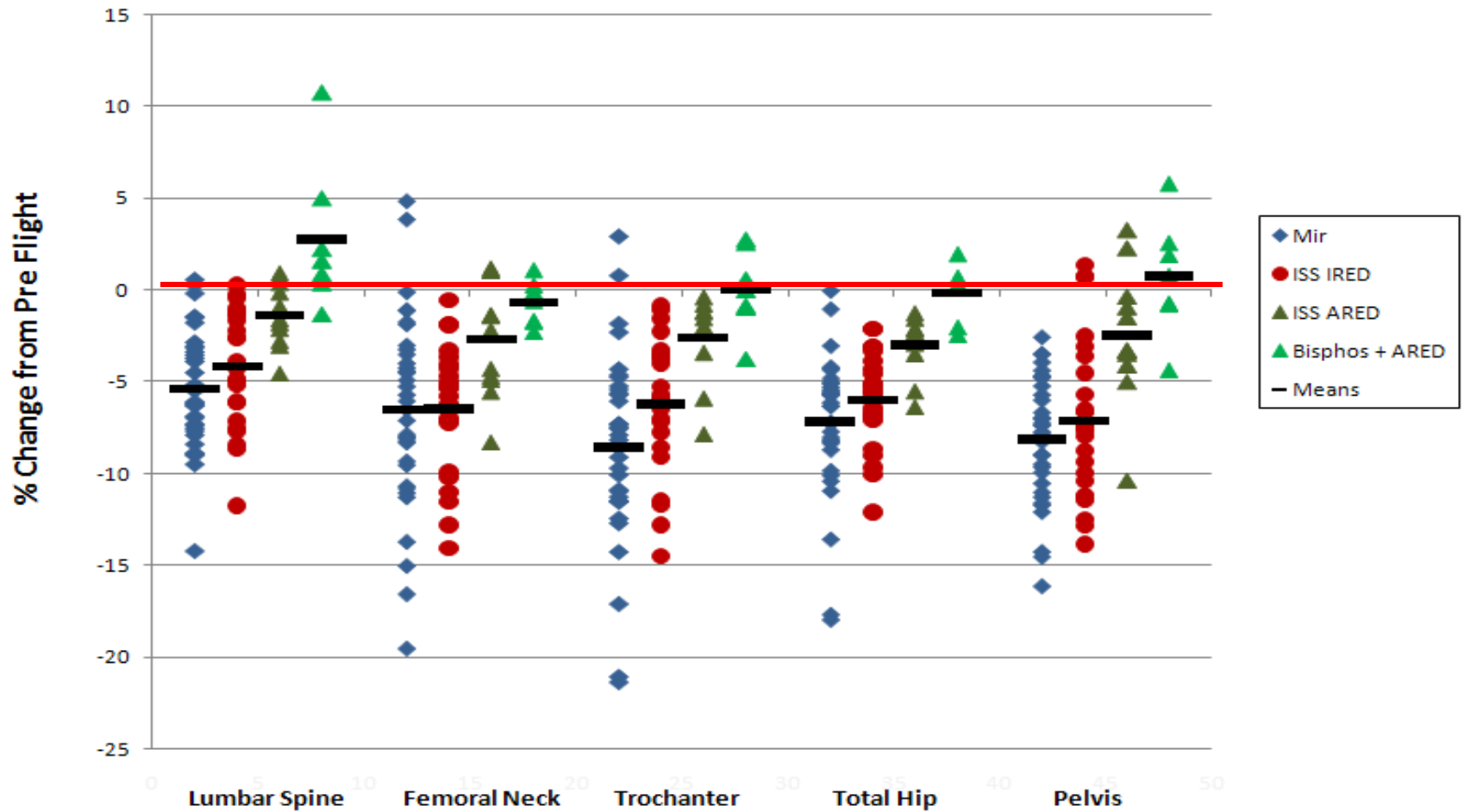
Muscle Function

Exp 1-32 (IRED n=22 ARED+T2 n=25)



% Change in DXA BMD after Long-Duration Mir and ISS Missions

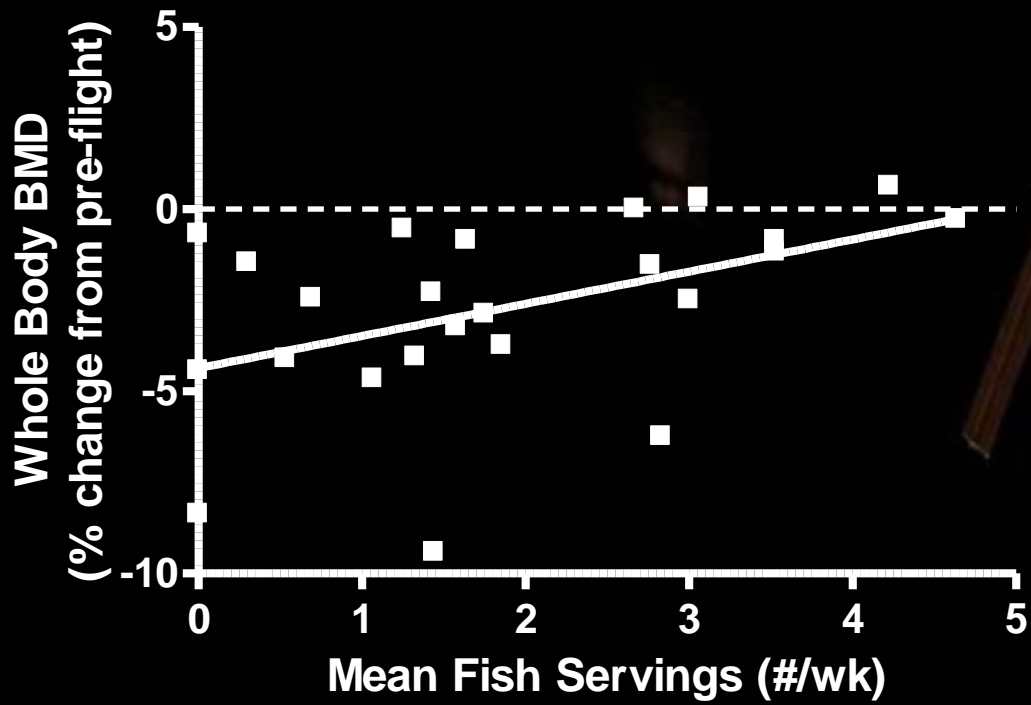
Mir n=35; ISS IRED n=24; ISS ARED n=11; Bisphos + ARED n=7



1217

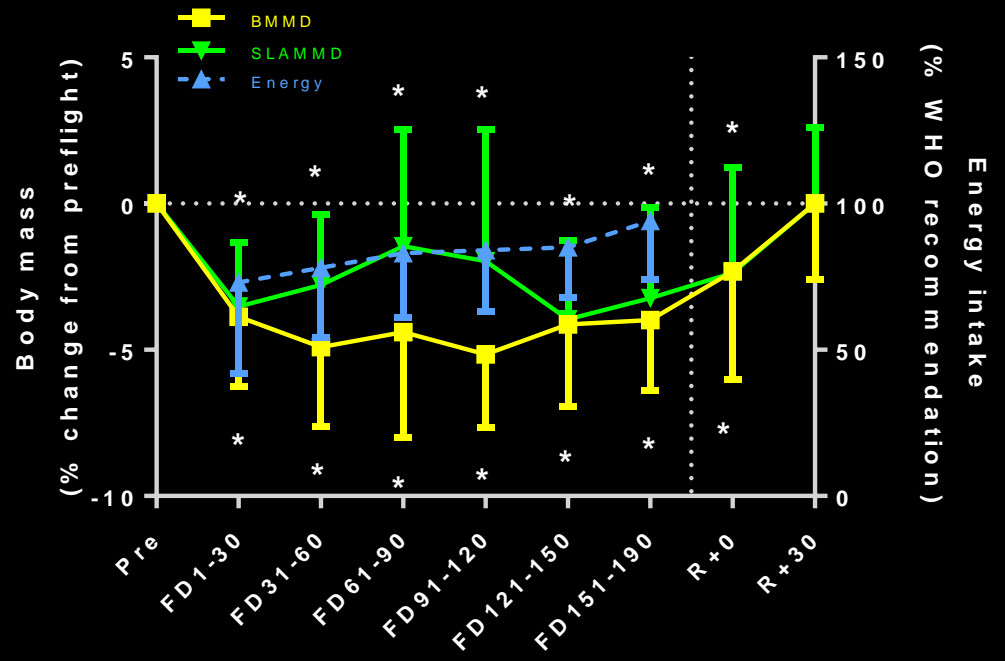
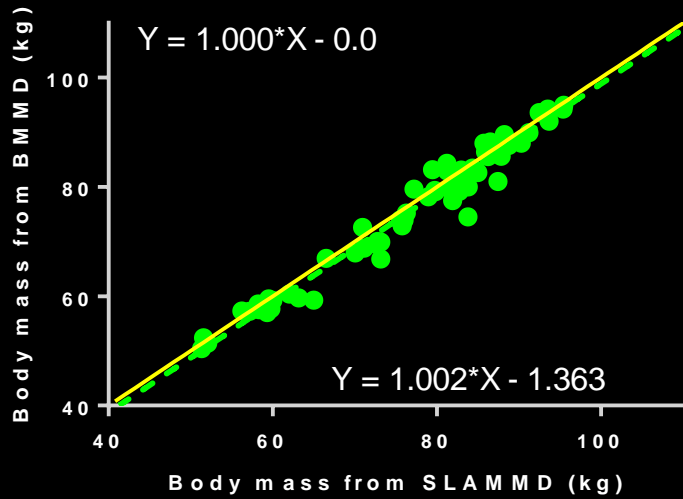
* Updated data since 2010 Bone Summit

Sibonga et al. 2014

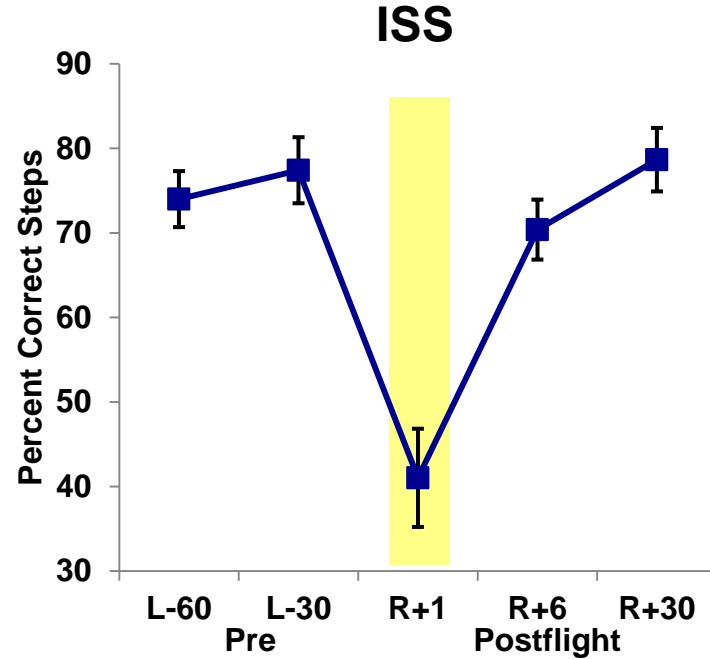
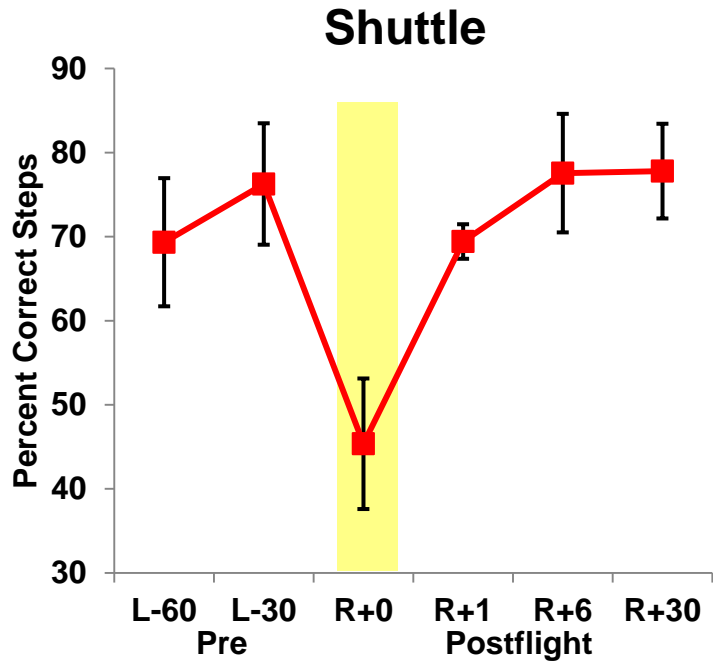


Smith et al. 2010

Body Mass



Tandem Walk Test



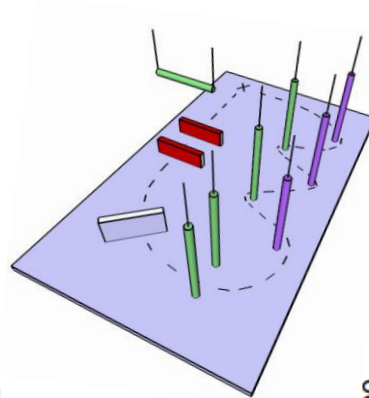
Incorrect Steps:

sidestepped, opened eyes,
or paused for more than
three seconds between steps



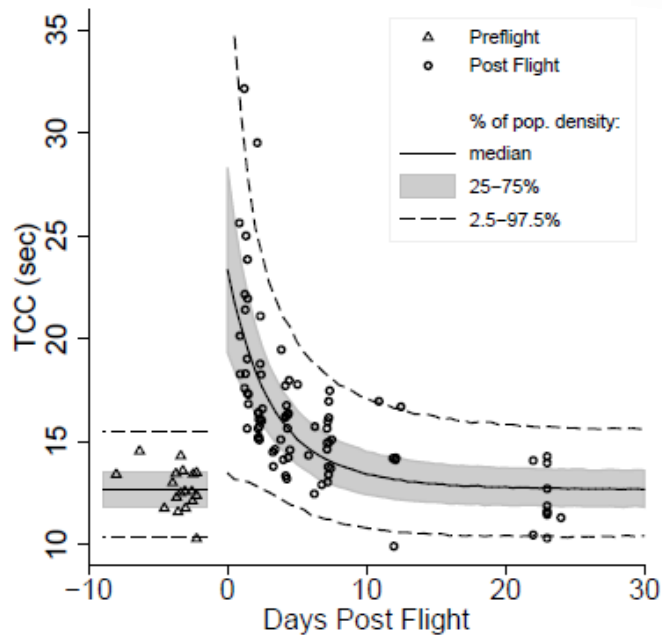
Bloomberg et al. 2014

Functional Mobility after Long-Duration Spaceflight (ISS)



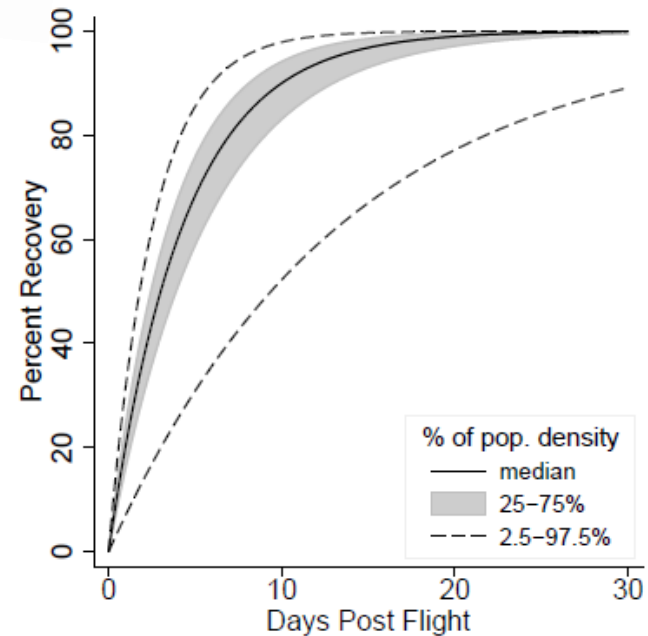
Functional Mobility Test

Time to Complete Course



N = 18

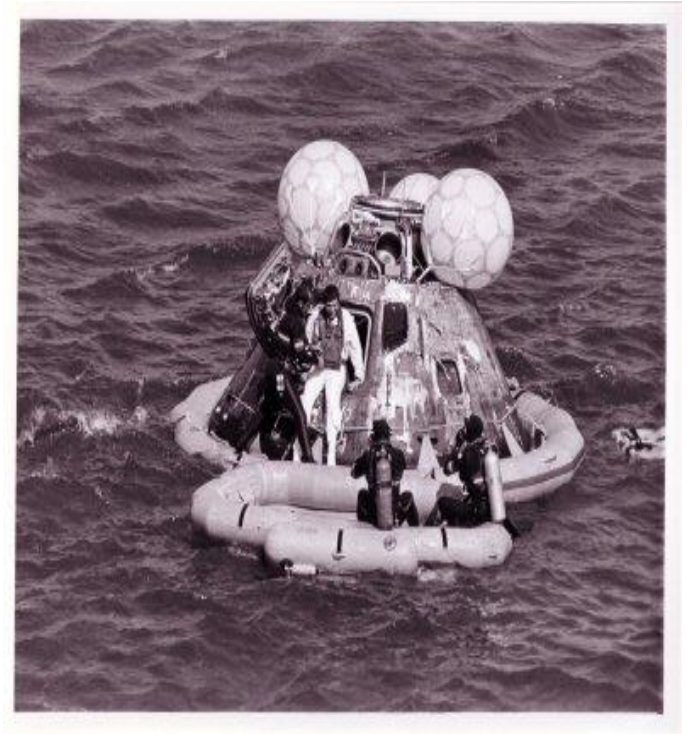
Percent Recovery



- Subjects showed a 48% increase in time to complete the course on R+1
- Recovery of functional mobility to 95% of preflight level took 15 days

Considerations from Apollo

- Apollo 17 splashdown
 - 12.5 day mission, 3 day lunar stay
 - <https://www.youtube.com/watch?v=c2mDEdCJlc>
 - Jack Schmitt, Ron Evans, Gene Cernan
- Biomedical Results of Apollo (<http://history.nasa.gov/SP-368/s3ch8.htm>):
 - With one important exception on the Apollo 15 mission, no crewmen experienced pronounced vestibular disturbances after returning from space flight. This finding suggests that adaptive processes that occur during weightless space flight missions of up to two weeks in duration do not render the vestibular system significantly hyposensitive or hypersensitive following sudden return to a one-g environment.
 - ✓ 33 subjects, 12 landed on moon, 6 to 12 day missions
 - Whether or not an individual is likely to develop inflight vestibular problems cannot be predicted reliably from his previous history of motion sickness.
 - **Data relied heavily on crew self-reporting**
- Principles of Clinical Medicine for Space Flight (Barratt,



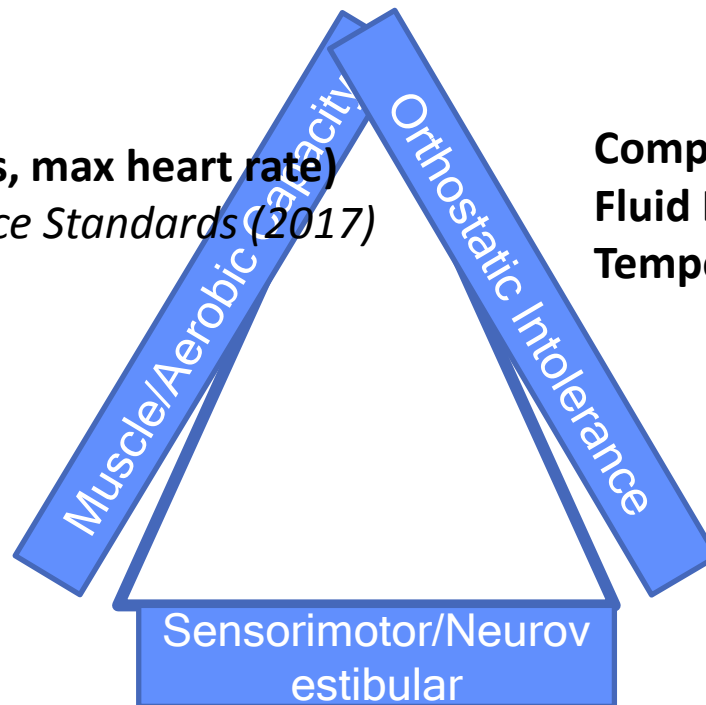
*Jack Schmitt egressing Apollo 17
Command Module*

Recommended MPCV Countermeasures (Date Available)

Inflight Exercise

(max contractions, max heart rate)

Preflight Performance Standards (2017)



Compression Garments

Fluid Loading

Temperature Control

Preflight Adaptation Training (today)

Inflight Load + balance challenge (2018 MPCV AEC)

Vehicle/Suit/Operations design (in work)

Status of Integrated Sensorimotor Countermeasures

Sensorimotor Countermeasures	CRL	Reference
Preflight Sensorimotor Adaptability Training (w/ Stochastic Resonance)	CRL 5	Sensorimotor Adaptability Training Review Paper
Visual Flow/Virtual Reality with Treadmill walking (high % body loading)	CRL 4	Sensorimotor Adaptability Training Review Paper/ FTT final report
Inflight balance challenge with load	CRL 4	FTT final report
Space Motion Sickness Training	CRL 4	Preflight Adaptation Training and AFTE manuscripts and reports

Balance/Sensorimotor Adaptability Training



Preflight

Sensorimotor Adaptability Training

- Support surface motion (motion base treadmill system)
- Altered visual information



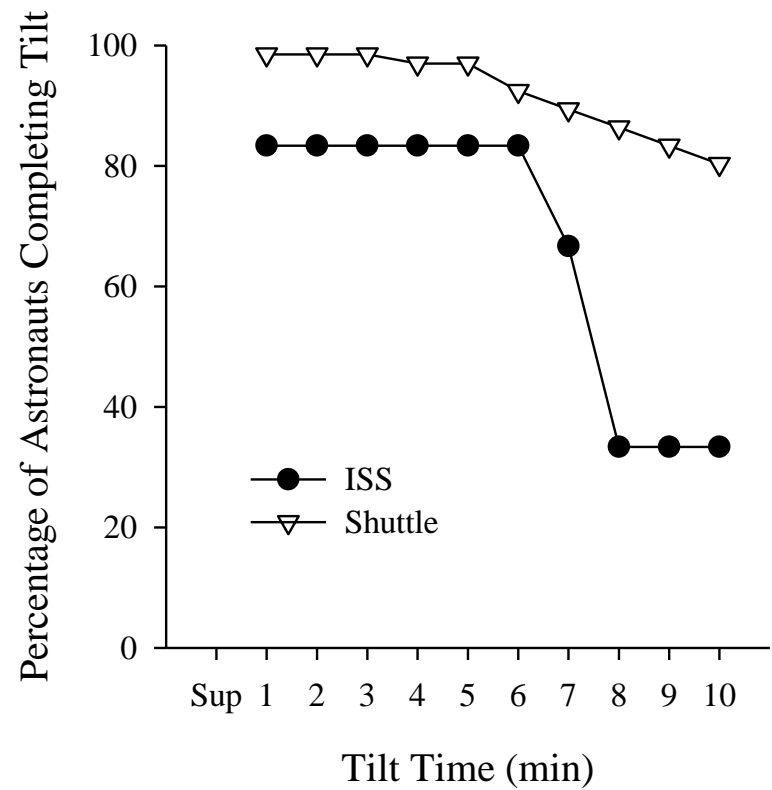
Inflight

Balance and Sensorimotor Adaptability Training

- **Treadmill Walking:** 1-g body load, variation in head movements and visual flow
- **Balance Training:** Self-directed perturbations on unstable surface, 1-g body load, visual flow



Stenger et al., Pers. Com. 2015).

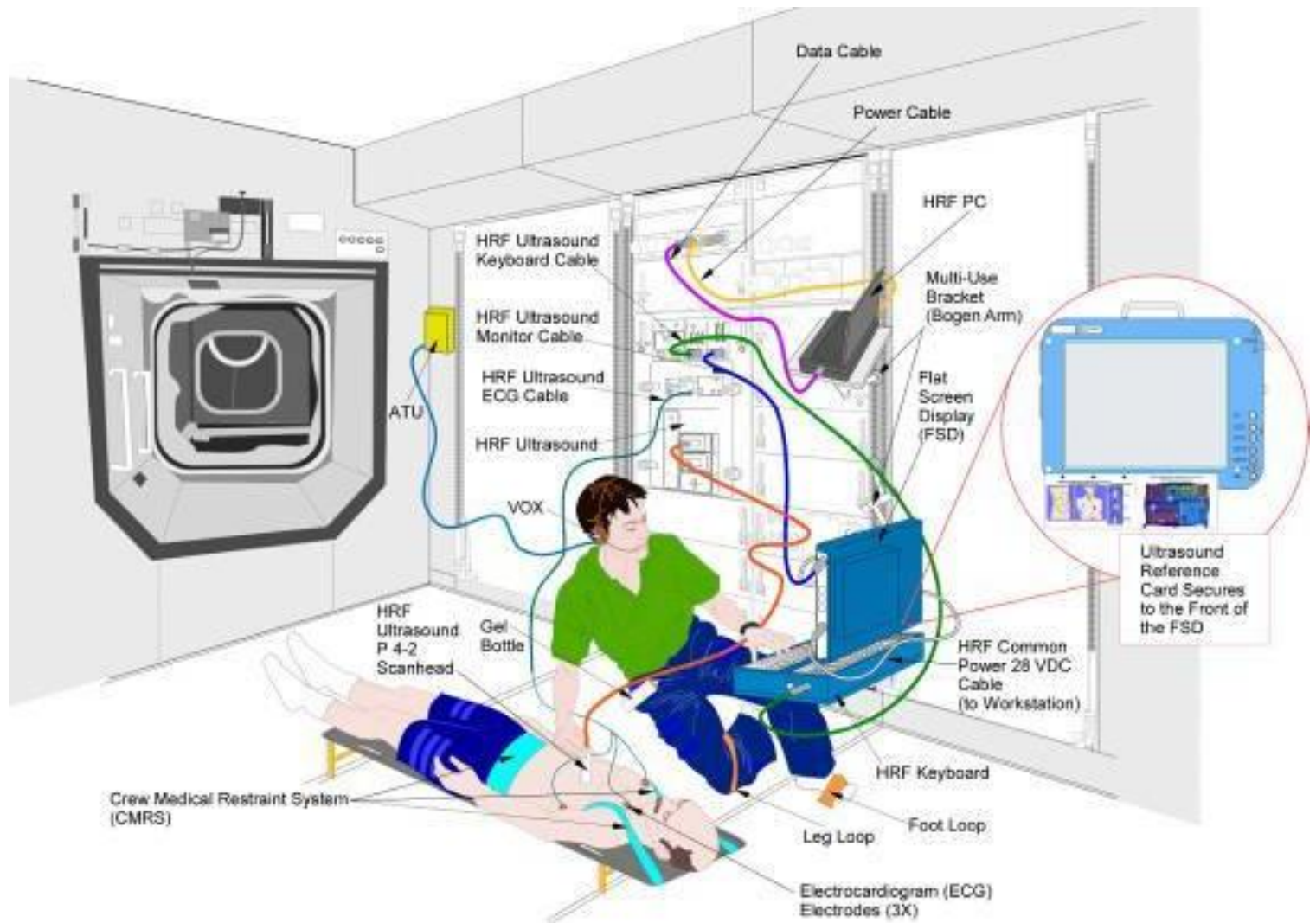


Orthostatic Intolerance

- Mitigated by:
 - Oral salt and fluid loading
 - Antigravity garment
 - Additional clinical i.v fluid treatment

Platts et al. 2012





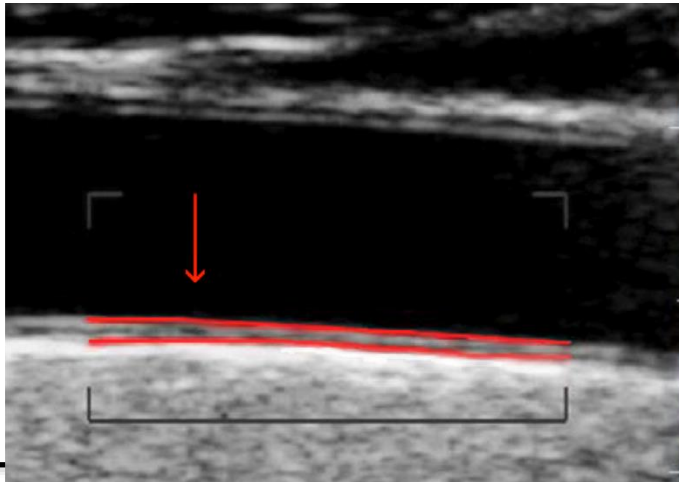
Vascular Effects - II



Arbeille - 2014 - Assessment of the Carotid and Femoral Arteries wall thickness during 6 month ISS Flights (Vessel Imaging Experiment) 35th Annual International Gravitational Physiology Meeting

**Carotid Artery Intimal Media Thickness (IMT), a subclinical precursor to atherosclerosis, increased by 15% between FD 110 – FD 135 as compared to FD 15 (n=10)
Remained elevated at R+4 testing.**

(Arbeille et al. 2014, ISGP Waterloo).





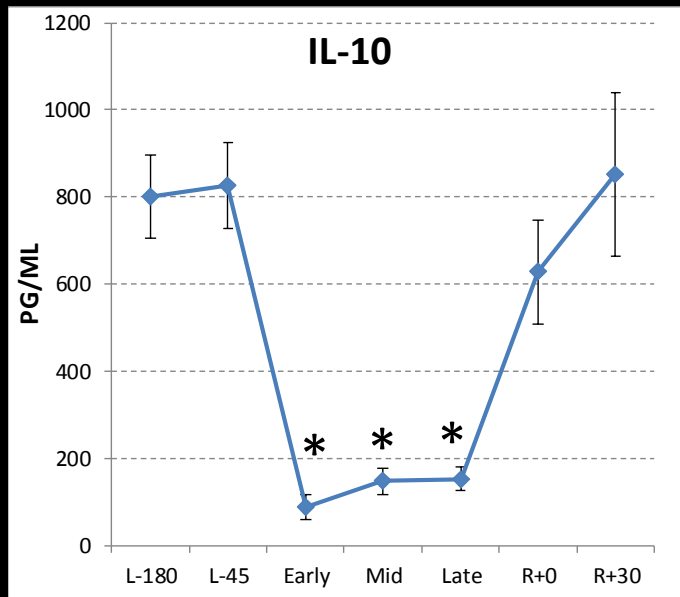
- **Weightlessness**
- **Radiation**
- **Isolation**
- **Stress**
- **Distance**
- **PO₂-PCO₂-changes**
- **Circadian rhythms**
- **Other**

Synergistic effects?



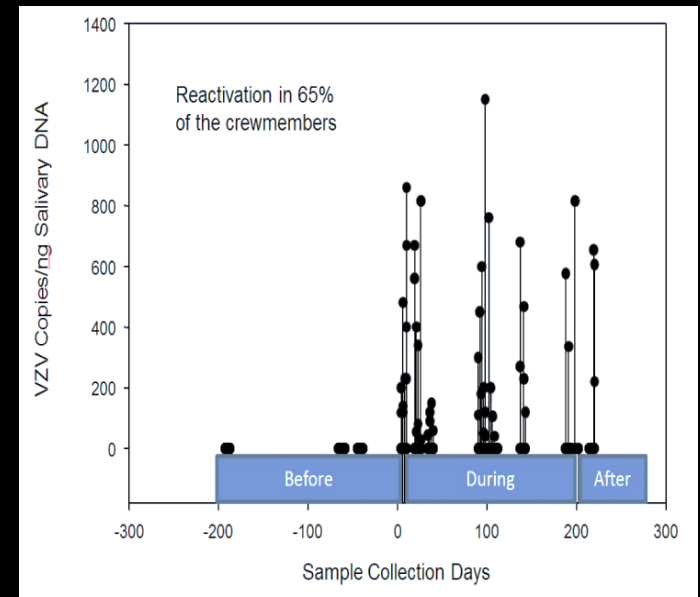
Immunity is Altered During Long-duration Spaceflight onboard ISS

Cytokine Production Profiles



N = 22

Latent Herpesvirus Reactivation



Crucian et al. 2014

VIIP Syndrome

Fluid shift induced vision and intracranial pressure changes!

Example of cephalad fluid shift

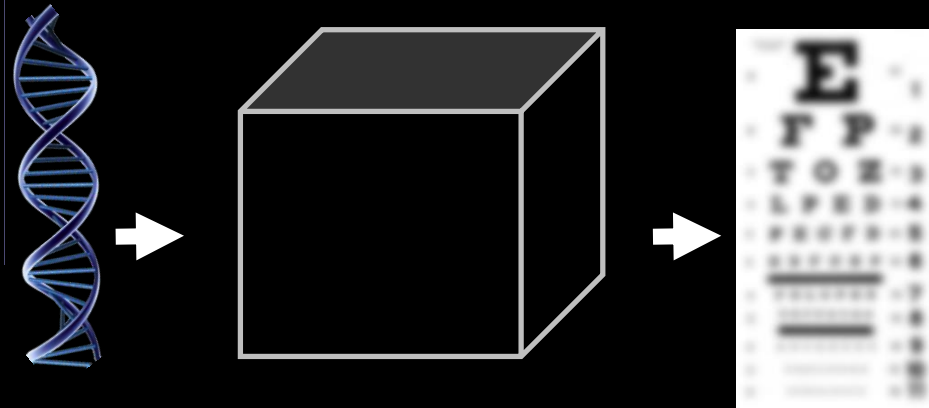
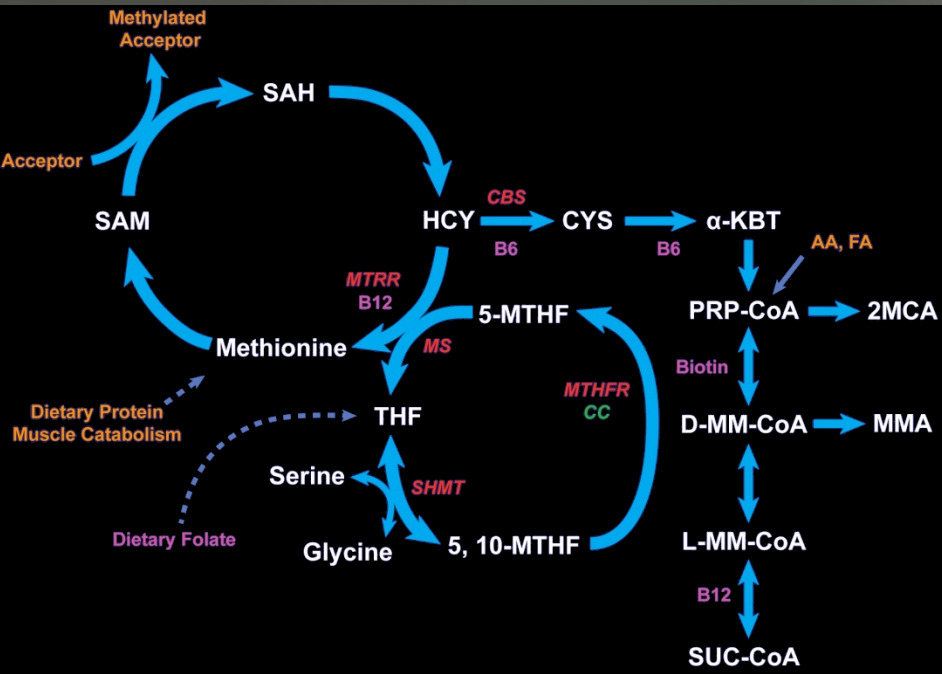
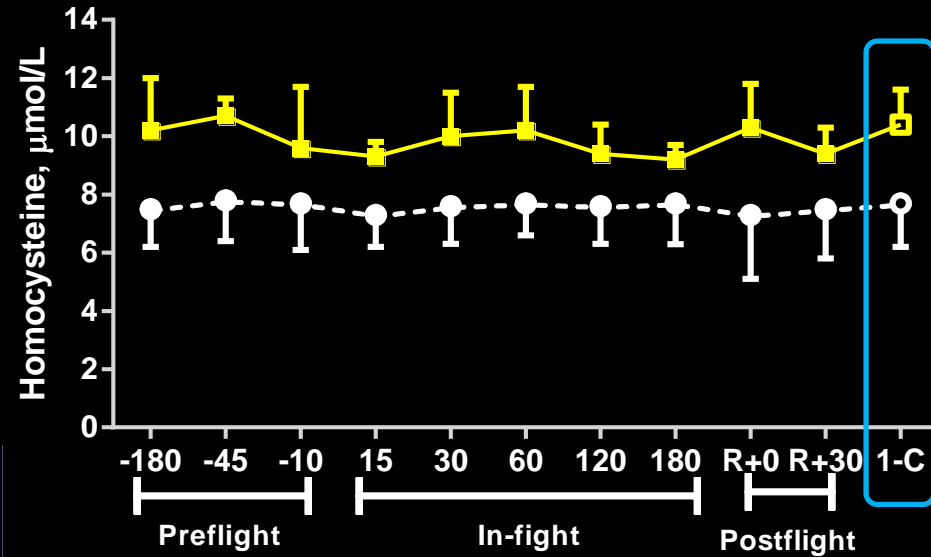
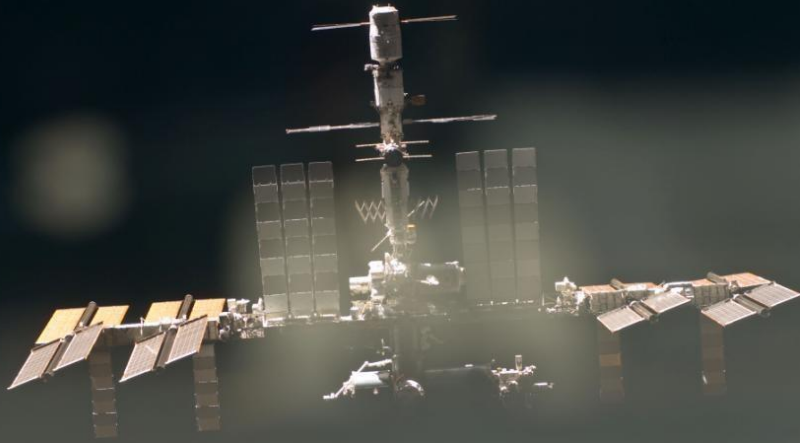


Preflight press briefing



FD-2

One Carbon Metabolism/VIIP



Future approach

IPCS:

IPCS:

IPCS:

Integrated
Physiological
Countermeasure
Suite

Based on ISS Research



Integrated Physiological Countermeasure Suite

Pre-flight

- Establish healthy life style: Exercise, food intake
- Develop individualized CM-protection programs: Computer modeling, G-transition training



Integrated Physiological Countermeasure Suite

In-flight

Monitoring

- Immune/OSaD-biomarkers (Lab analysis of urine, blood, saliva)
- Cardiovascular, VIIP, muscle/bone (ultrasound, ECG, BP, OCT, CCFP/TCD, vision, cognition)

Training & Prevention

- Sensory-motor adaptability training: Computer programs , vestibular (galvanic) stimulation
- Exercise prescriptions: Aerobic and resistive
- EVA pre-breathing
- Functional food items: Omega-3, anti-oxidants, low salt and iron
- Anti-osteoporotic medications: Bisphosphonates, anabolics, ACE-inhibitors

Treatment and prevention

- Anti-VIIP bracelets (+/- dynamic exercise) and/or medication
- Anti-motion sickness & anti-inflammatory medications (medication stability monitoring)
- Anti-orthostatic pre-landing fluid and salt ingestion



Integrated Physiological Countermeasure Suite

Planetary landing

- Anti-orthostatic garment and fluid/salt treatment
- G-transition medication, vestibular (galvanic) stimulation



Integrated Physiological Countermeasure Suite

Pre-flight

- Establish healthy life style: Exercise, food intake
- Develop individualized CM-protection programs: Computer modeling, G-transition training

In-flight

Monitoring

- Immune/OSaD-biomarkers (Lab analysis of urine, blood, saliva)
- Cardiovascular, VIIP, muscle/bone (ultrasound, ECG, BP, OCT, CCFP/TCD, vision, cognition)

Training & Prevention

- Sensory-motor adaptability training: Computer programs , vestibular (galvanic) stimulation
- Exercise prescriptions: Aerobic and resistive
- EVA pre-breathing
- Functional food items: Omega-3, anti-oxidants, low salt and iron
- Anti-osteoporotic medications: Bisphosphonates, anabolics, ACE-inhibitors

Treatment and prevention

- Anti-VIIP bracelets (+/- dynamic exercise) and/or medication
- Anti-motion sickness & anti-inflammatory medications (medication stability monitoring)
- Anti-orthostatic pre-landing fluid and salt ingestion

Planetary landing:

- Anti-orthostatic garment and fluid/salt treatment
- G-transition medication, vestibular (galvanic) stimulation

But -

But – why not bring gravity?

Example of cephalad fluid shift

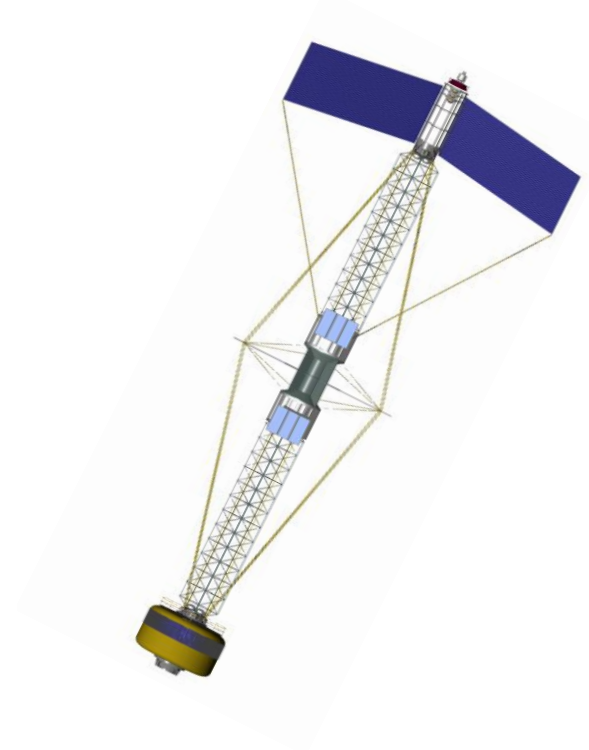
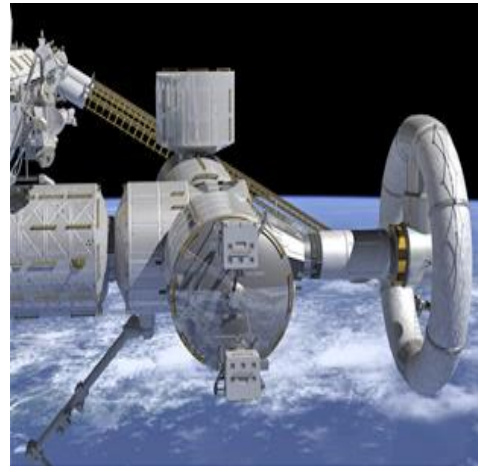
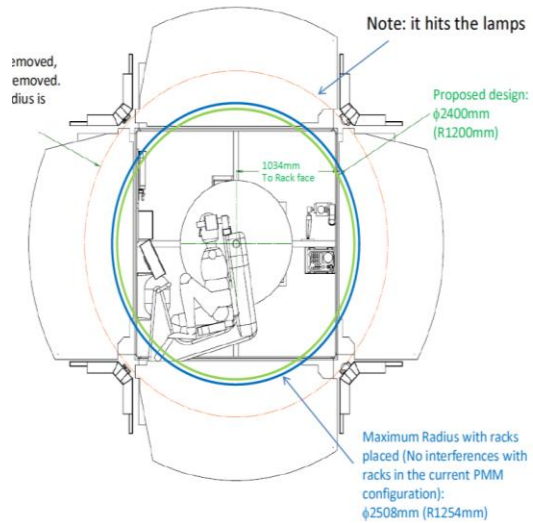


Preflight press briefing



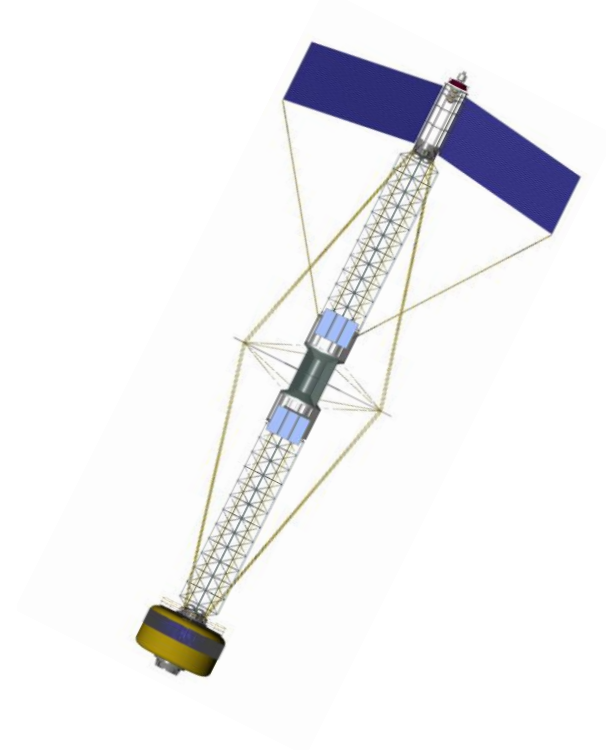
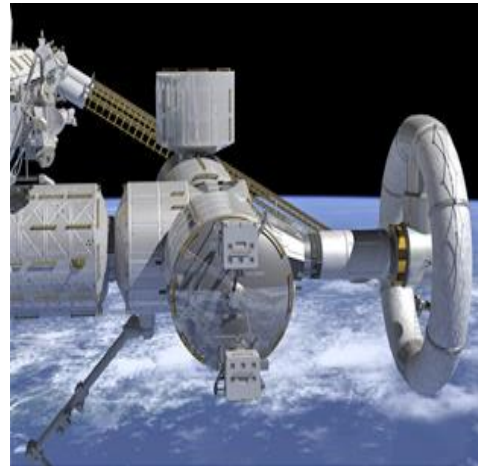
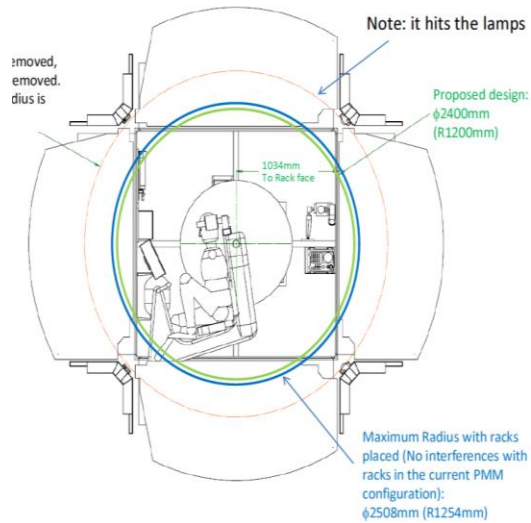
FD-2

Artificial Gravity



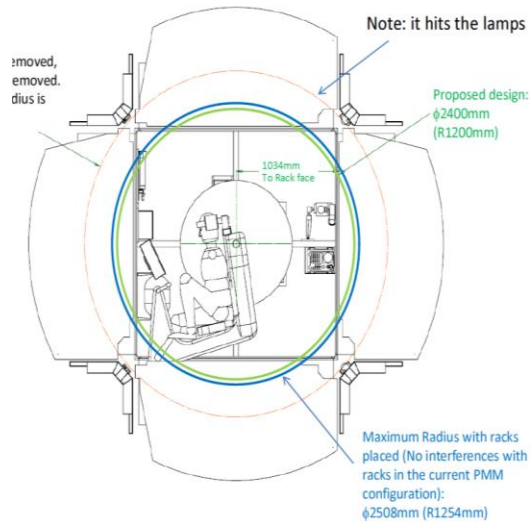
Spinning:

Artificial Gravity

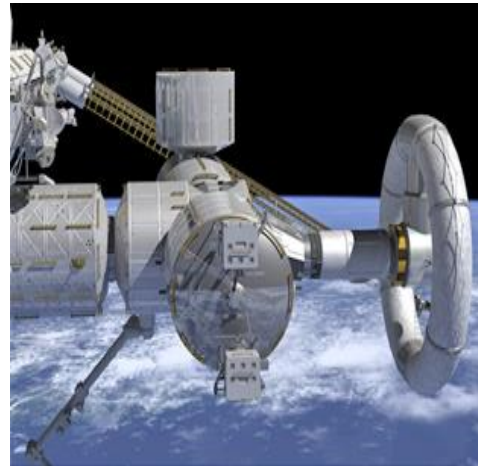


Spinning:
Inside

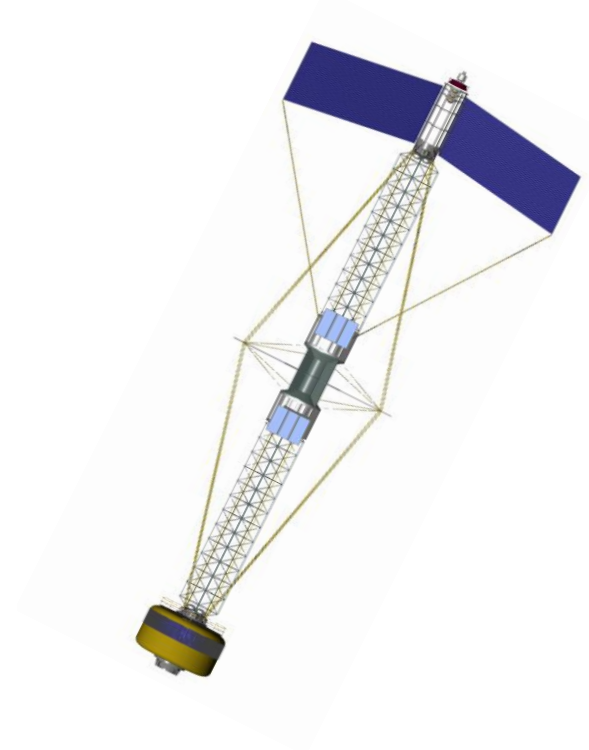
Artificial Gravity



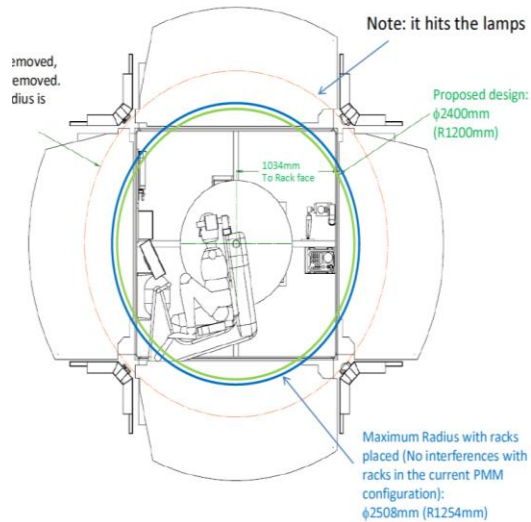
Spinning:
Inside



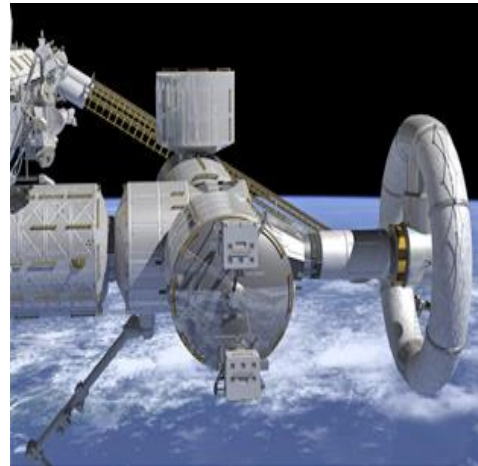
Part of



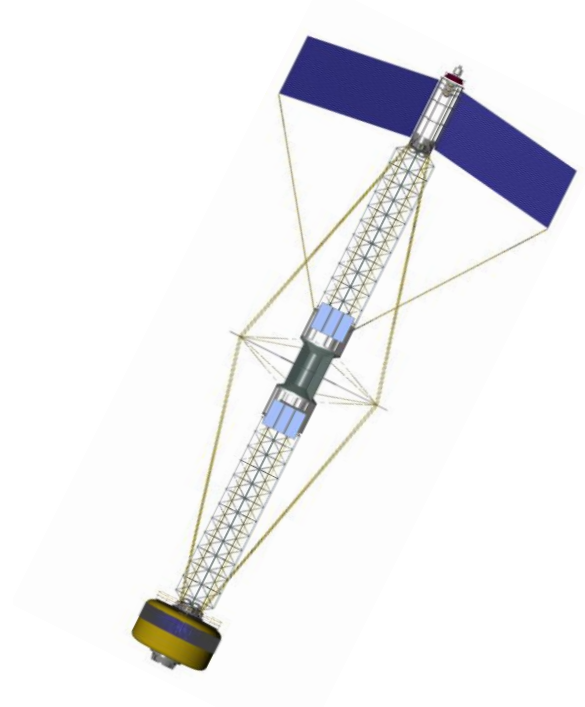
Artificial Gravity



Spinning:
Inside

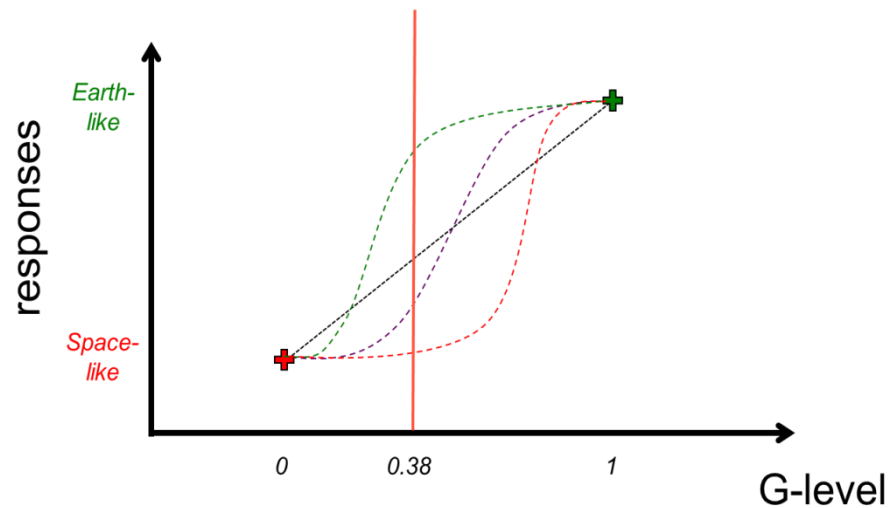


Part of



Whole vehicle

Physiological Responses to Hypogravity?



We don't know:

- The minimum artificial gravity level?
- The protection of Martian gravity?

Paloski 2014



Thank
you!